Managing Vibrations, Go to the Source(s)

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Introduction

Managing mechanical stability involves work on different areas in order to reach the goal of delivering stable conditions for the measurements at the beamlines. One of the obvious places, and often most cost effective, is to reduce the influence by sources. Here is described the work, done at MAX IV, in order to reduce the contribution from what is often called cultural noise. Cooling water pumps and vacuum pumps are used as examples. One of the problems which is not easy to solve is also exemplified.

Some Examples of Vibration Isolation

Stationary vibration sources are often easily isolated by using springs.
The transmissibility curve show that isolating an oscillating source is best done by putting it an a system with much lower Eigenfrequency than the driving frequency. A good rule of thumb is ω/ω_n**>5** Also there should be as little damping as possible except if resonance amplitudes are relevant.

Isolation of Cooling Water Pumps for the main supply. All local shunt groups for accelerators and beamlines are also isolated. The concrete slaps are situated on springs.

Isolation of vacuum Pumps

The new **SPELEEM** end station at beamline **I311** at MAX II had difficulties with blurred images. Several backing vacuum pumps and also the connecting hoses were isolated. At the sample holder the vibration contribution from pumps went down 89%. The overall vibration level at the sample holder was reduced by 46%. After the simple and inexpensive remedy the microscope works as expected.

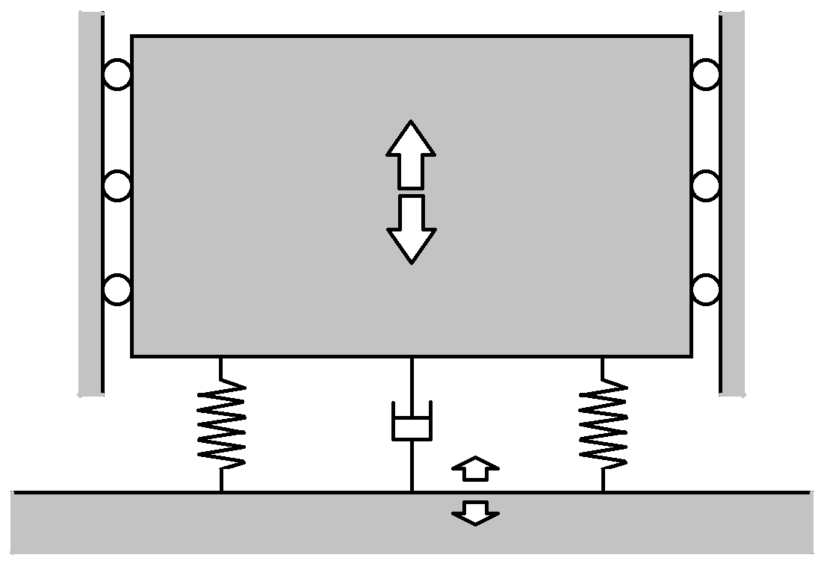
There are plans to build a tram line from the central to the site for MAX IV and ESS.
The nearest 500m of the tracks will be isolated as illustrated.
Calculations show that this remedy is sufficient for the safe operations of MAX IV.

Isolation of Tram Line Tracks (an example). [1]

Transmissibility

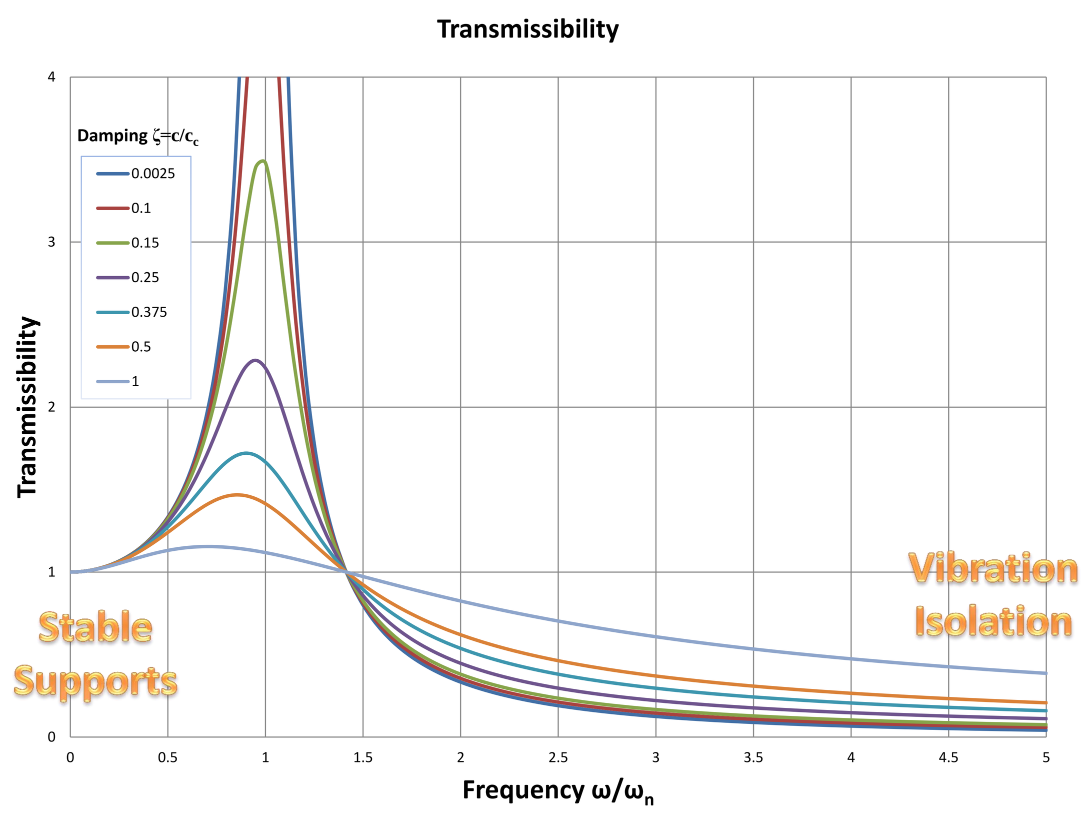
Understanding the fundamentals behind transmissibility is important when managing mechanical stability issues. Here is shown a one-dimensional system with a mass, sitting on springs and a dampener. Transmissibility is the transfer ratio of force or vibration. All practical items have multiple (sometimes indefinite) **D**egrees **O**f **F**reedom (DOF). The principle is the same for multiple DOF-systems.

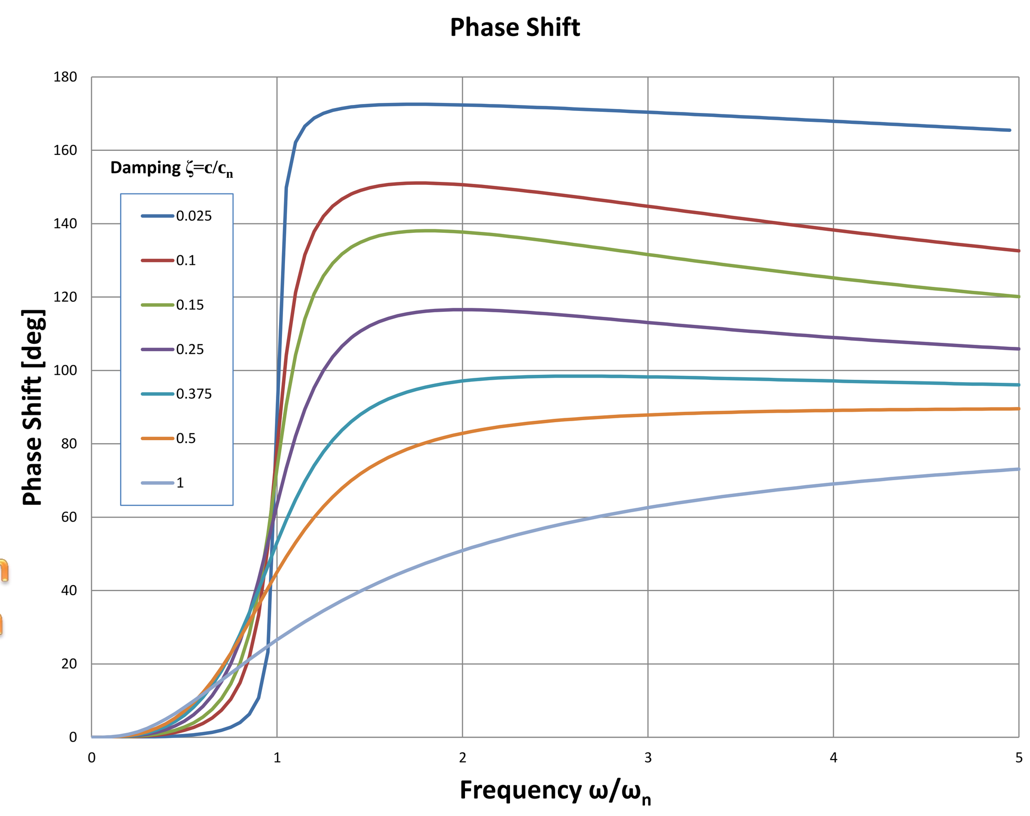
- If the mass is subjected to an oscillating force, the transmissibility is the ratio of the force going through to the floor. This is used when **isolating** a pump for example.
- If the floor is vibrating (i.e. an oscillating floor level), the transmissibility is the ratio of the displacement of the mass relative to the floor displacement. This is the **amplification** of the floor vibrations for a mirror or a magnet sitting on a support.



Transmissibility is the transfer ratio of force or vibration. (One dimensional schematic)

The transmissibility curves are valid for both cases and are here shown in normalized units (c_c = damping coefficient for critical damping. ω_n = resonance frequency). Also the phase shift between the input and the reaction is shown. This is a text book example, see for example [2].





Developing Floor and Supports

When designing supports the mission is to not amplify the vibrations of the floor. Most often magnets or optical components need to be stationary relative to other components. Then the isolation option disappears, so aiming for $\omega_/ \omega_n$<1/3 is a good rule of thumb. The main part of the vibrations at MAX IV is in the range 7-15Hz [3].

When designing supports for the MAX IV facility we are aiming for **Eigenfrequencies>55Hz**. With this rule the amplification is moderate and also the **phase shifts** are moderate. The floor design work was aimed at getting high **correlation**. Small amplification and phase shift ensure that the equipment on the support is following the floor.

High correlation, **low amplification** and **small phase shifts** ensure that accelerator parts and beamline components move "in concert" over a longer distance. This is **decreasing** the **sensitivity to vibrations**.

Special Cases

Sometimes it will not work going "light and stiff" for supports or "heavy and soft" for isolation.
An **internally cooled mirror**, is subjected to forces induced by turbulent flow. The mirror vibrations are growing with the force, but they are reduced by adding inertia to the mirror. The challenge here is to increase inertia, but also the stiffness to maintain proper performance. Doing this for mechanical systems, which also have very tight tolerances on motion control (for monochromators) is a difficult task.

System	Low Inertia	High Inertia
Stiff	**Stable Supports for Facility Components** **Self-Supporting Magnets**	**Internally Cooled Optical Systems** **Facility Floors**
Soft	Acoustical Damping? Dissipation of Energy?	**Vibration Isolating systems** **Water Pump Pulsation Isolation**

Matrix of system properties with examples of use.

Project Proposal

It is not possible to calculate the force spectrum for turbulent flow in ducts. The proposal is to make a test setup to measure force spectra for different relevant geometries like cooling tubes or internal cooling channels.
When the force spectrum is known for a given setup it is possible to calculate on the effect on systems, using FEA. This could reduce the risk of malfunction, but also "overkill" designs.

References

[1] Ramböll, "Spårväg Lund C till ESS – buller och vibrationer".
[2] William Thomson, "Theory of Vibration with Applications", 2nd ed.
[3] PEAB et al. "20110012-00-3-TN MaxLabIV Indata till beräkningarna.pdf"

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The MAX IV Laboratory

The MAX IV Laboratory opened for operation in 1987 (under the name MAX-lab) and is a national laboratory operated jointly by the Swedish Research Council and Lund University. The laboratory supports three distinct research areas: Accelerator Physics, Research based on the use of Synchrotron Radiation, and Nuclear Physics using high energy electrons.

At present three synchrotron storage rings are in operation MAX I-III and each year close to 1000 researchers visit the laboratory to perform experiments. The MAX IV laboratory is also responsible for the build up of the MAX IV facility situated in the Brunnshög area just outside of Lund and approximately 2 km from the present facility.

MEDSI2014, October 20th –October 24th 2014, Melbourne